

The effect of a transpalatal arch for the correction of first molar rotation

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SUMMARY The effects of a transpalatal arch for the symmetrical derotation of rotated first molars were evaluated in 50 children, 8–13 years of age. The positions of the molars were compared with those in 34 individuals, aged 12–18 years, with normal occlusion. Prefabricated (GAC) stainless steel arches were used for 60–198 days (median time 122 days). The effect was recorded with a measuring microscope on dental casts from before and after the treatment. Molar positions were determined from the tips of the four cusps of the tooth in relation to a coordinate system based on palatal reference points. The centre of rotation of the molars during derotation were calculated from the movement of their cusps.

Before derotation the first molars were significantly mesiopalatally rotated compared with the normal occlusion group. The derotation overcompensated the initial rotation. In about two-thirds of the cases the mesiobuccal cusp of the molar moved distally during the derotation. In the remaining cases it moved mesially or remained unchanged. The median distal movement was 0.3 mm on the right and 0.5 mm on the left side. Because many molars moved mesially, on average there was no gain in space in the dental arch from the derotation. The location of the centre of derotation varied widely but it was on average located midway between the distobuccal and distopalatal cusps. In most cases the derotation resulted in a small, unintended, expansion. The study showed that mesiopalatally rotated first molars can effectively be derotated with a transpalatal arch. The effect on the mesiodistal position of the mesiobuccal cusp, and particularly with regard to space gain, is, however, unpredictable.

Introduction

The maxillary first molars are often rotated with the mesiobuccal cusp displaced in a palatal direction. The consequences of the malposition are that the tooth occupies excessive space in the dental arch and that the buccal cusps occlude with a tendency to a Class II molar relationship. The palatal cusp, however, often occludes correctly in the fossa of the opposing molar.

Several authors have described parameters with which to judge the position of the molar. Henry (1956) measured the angle between the median raphe and a line through the buccal cusps of the molar. Friel (1959) also used the median raphe as a reference and measured the angle between the raphe and a line through the mesiobuccal and mesiopalatal cusps of the molar. Orton (1966) used the angle between a

line tangent to the buccal surfaces of the premolars and a line tangent to the buccal surface of the molar. Finally, Ricketts (1969) described a line through the mesiopalatal and distobuccal cusps of the molar. If this line passes the distal half of the canine on the contralateral side the molar is positioned correctly. A rule for the clinical evaluation of the position of the upper first molars has been given by Cetlin (cited in McNamara and Brudon, 1993). According to this rule, the buccal surfaces of the molars should be parallel when viewed from the anterior.

One of the most efficient appliances for the derotation of molars is the transpalatal arch. This appliance is especially favourable when the need for derotation is the same on both sides of the dental arch. Equal and opposite moments of rotation can then be used without the creation of forces in the mesiodistal direction. Such

forces are the inevitable result of unequal moments on the two sides (Fig. 1). Molar derotation is often undertaken in order to gain space in the dental arch. In such cases mesiodistal forces are unwanted because they would lead to a mesial movement of the molar subjected to the largest derotating moment. Mesiodistal forces may be used to advantage, however, in a case where the molar on one side needs to be moved mesially and that on the opposite side distally. This is, however, not the average case for molar derotation.

In an earlier study the moments and forces delivered by transpalatal arches, activated for symmetrical first molar rotation, were measured in laboratory experiments (Ingervall *et al.*, 1996). It was found that in spite of the precautions possible in the standardized conditions of laboratory experiments the ideal symmetric force system could not be attained. Therefore, mesiodistal forces were regularly recorded. It was also found that during the course of molar rotation contractive forces between the contralateral molars developed. These forces were not very large but needed to be compensated for in order to prevent a tendency for crossbite of the molars to develop during their rotation.

The present investigation is a complement to

the laboratory experiments performed in order to study the movement of the first molars when a transpalatal arch is used for molar derotation in the clinical setting. Derotation of rotated upper first molars has gained in importance with the present trend towards non-extraction treatment (Ten Hove, 1985). The theory is that derotation of rotated molars will result in some space gain. Thus in a borderline case, derotation can be a factor for a non-extraction treatment plan. The aim of the present study was to evaluate clinically the amount of space that can be gained by molar derotation. An additional aim of the study was to test the correctness of the rules of Ricketts and of Cetlin for judgement of the rotational position of the upper first molar.

Subjects and methods

Two series of subjects were studied. The first series (ideal occlusion group) comprised 15 boys and 19 girls, aged 12–18 years (median age 14 years). These subjects were selected in the late 1960s by a competition arranged by the Swiss Dental Society. The aim of the competition was to find individuals with a young permanent dentition with relatively few fillings, well developed dental arches without space problems and good occlusion. Further criteria for the selection were the presence of all permanent teeth (third molars excluded) in good positions and no previous orthodontic treatment. At the time of the competition the cases were selected by a panel of orthodontists. The dental casts of these individuals were used as an 'ideal occlusion group' in the present study and were included as a reference for the evaluation of the validity of the rules of Ricketts and of Cetlin for correctly positioned upper first molars.

The second series (treatment group) consisted of 14 boys and 36 girls, aged 7 years, 9 months to 12 years, 11 months (median age 10 years, 2 months) with rotated upper first permanent molars that were to be treated at the Orthodontic Clinic, University of Bern, Switzerland. All children had a mixed dentition; none had the maxillary second permanent molars erupted at the start or at the end of the treatment.

Treatment

The molars were derotated with a prefabricated transpalatal arch manufactured by GAC (GAC

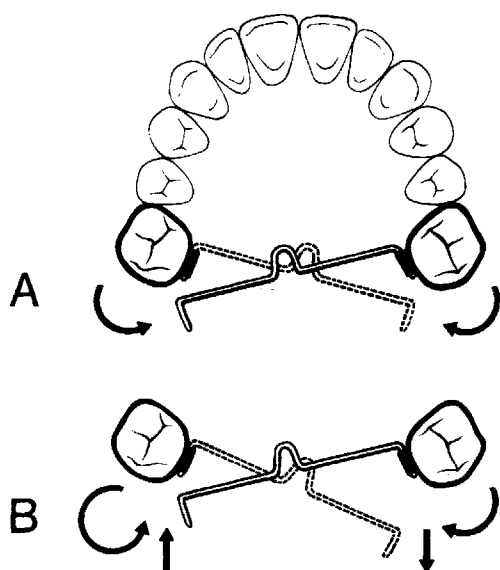


Figure 1 Moments and forces delivered by a transpalatal arch activated for symmetrical (A) and for asymmetrical (B) molar derotation. Note the mesiodistal forces resulting from unequal moments on the two sides.

International Inc., Central Islip, New York, USA). The arch was round and made of stainless steel with a diameter of 0.036 inches (0.91 mm). The arch had a mesially directed loop in the middle and was bent back on itself at the ends to fit in prefabricated rectangular tubes (Ormco; Sybron Corporation, Glendora, CA, USA) on the palatal side of the molar bands. The arch was formed to follow the contour of the palate at a distance of 1–2 mm. It was made passive, which was checked by alternate insertion in the tube on the right and left sides. The activation for derotation was carried out by changing the angle between the double-ended part and the main arch so that when the arch was inserted in one tube, the other end was positioned 8 mm distal of the other tube (Fig. 2). The activation was done similarly on both sides in order to obtain a symmetric force system with an equal amount of derotation bilaterally. The activation was checked for symmetry by alternate insertion in the tubes on the two sides.

The time needed for derotation of the molars varied between 60 and 198 days (median 122 days). The appliance was checked and reactivated at 6-week intervals. In all cases a second activation was undertaken after 13–91 days (median 42 days). In 24 patients a third activation was done 47–134 days (median 87 days) after the start of the treatment. Only two subjects had the arch activated four times. The reactivation was performed using the same procedure as the original activation. During the

derotation no other maxillary appliance was used.

Measurements of tooth position

The positions of the maxillary first molars were measured on the dental cast of the ideal occlusion group and in the treatment group on dental casts made from alginate impressions taken before and after derotation. A coordinate system was used for the measurements. The *y* axis was the raphe line, which was identified by selecting distinct points in the anterior and posterior part of the palate identical on the casts taken before and after the treatment. The *x* axis was determined by the mean *y* coordinate of four distinct median rugae points; the two most anterior and the two most posterior rugae were used. (Fig. 3). The *x* axis was arbitrarily constructed 45 mm posterior of this point. Further reference points were the anatomical contact points of the deciduous or permanent canines as well as the contact points of the premolars or the deciduous molars. On the permanent first molars the tips of the four cusps were used. For the measurements the reference points were marked with a pencil. All measurements on the cast were made with a measuring microscope (magnification $\times 7$) connected to a computer as described by Gebauer (1977), delivering Cartesian coordinates.

The following measurements were made:

- i) The angle between the *y* axis and a line through the mesiobuccal and mesiopalatal

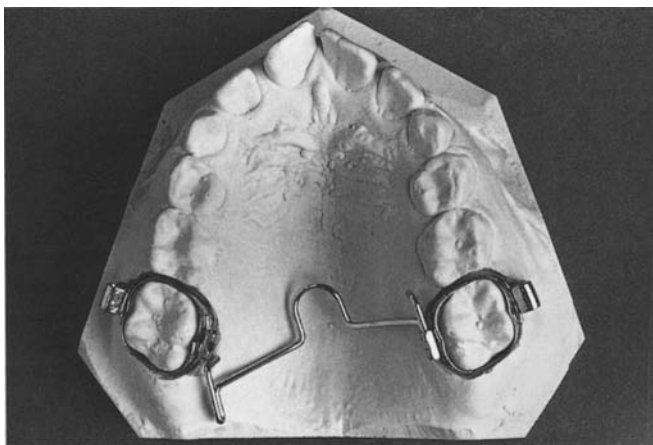


Figure 2 Position of the activated arch when inserted in one molar tube.

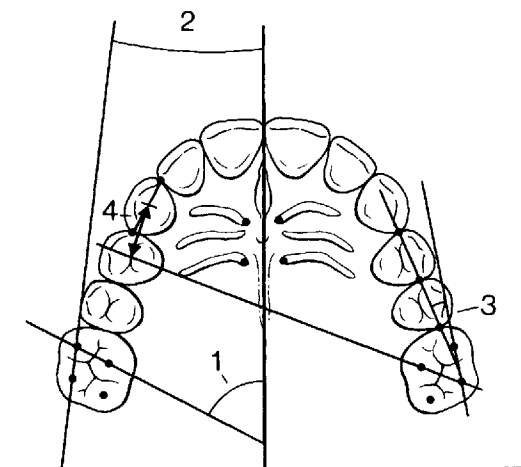


Figure 3 Coordinate system and reference points used by the measurement. The figure also shows angles 1, 2 and 3 as well as distance 4.

cusps of the molar (Fig. 3) in accordance with Friel (1959).

- ii) The angle between the y axis and a line through the buccal cusps of the first molar. This angle is the one used by Henry (1956). The angle was given a negative sign if it opened anteriorly.
- iii) The angle between a line through the contact points of the premolars and a line through the buccal cusps of the first molar. In cases where the contact points of the premolars were not in line, the mesial contact point of the first premolar and the distal contact point of the second premolar were used. In cases where one or both premolars had not yet erupted the contact points of the deciduous molar(s) were used. This angle is a modification of the one described by Orton (1966). The angle was given a negative sign if it opened posteriorly.
- iv) The smallest distance from the midpoint between the contact points of the contralateral canine and a line through the distobuccal and mesiopalatal cusps of the first molar. The distance was given a positive sign if measured distal of the midpoint of the canine and a minus sign if measured mesial of the midpoint. The distance is a quantification of the rule used by Ricketts

(1969) for the judgement of the position of the molar.

- v) The y coordinate of the midpoint between the mesiobuccal and mesiopalatal cusps of the first molar. This measurement was made in order to record anteroposterior movement of the molar during derotation (Fig. 4).
- vi) The y coordinate of the mesiobuccal cusp of the first molar. This measurement is an indication of the change in buccal intermaxillary relation of the molar during derotation (Fig. 4).
- vii) The x coordinate of the midpoint between the mesiopalatal and distobuccal cusps of the first molar (see Fig. 7). This measurement was made in order to record buccopalatal movement of the centre of the molar during derotation.

The centre of rotation of the molar during the derotation was calculated as follows: of the four cusps of the molar, the two with the largest displacement during derotation were selected. Lines connecting the positions of the cusps before and after derotation were constructed by a computer program. From the midpoint of the two lines (for the cusps one and two, respectively), perpendiculars were constructed. The point of intersection of the two perpendiculars constitutes the centre of derotation.

Measurements 1–4 were performed in both groups; in the treatment group before and after the treatment. The results for the ideal occlusion group were compared with those for the treat-

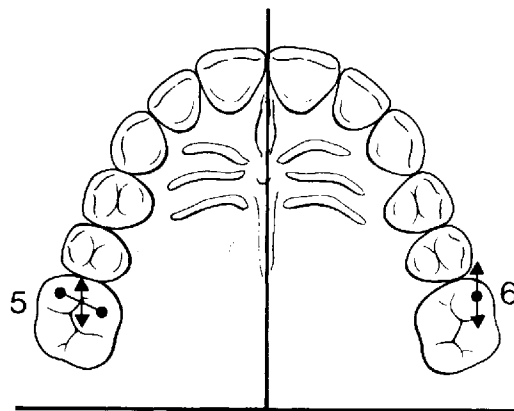


Figure 4 Measurements 5 and 6.

ment group (before and after the treatment). In addition, in the treatment group the measurements before treatment were compared with those made after treatment. Measurements 5–7 were made in the treatment group to evaluate the effect of the treatment.

Statistical analysis

Differences between paired observations were tested with Wilcoxon's matched pairs signed ranks test. Differences between independent samples were tested with Mann-Whitney's *U*-test. Relationships between variables were evaluated by Spearman rank correlations.

Errors of the method

The accidental errors of the method were evaluated by duplicate measurements of 20 randomly selected pairs of dental casts (one from before treatment and one after treatment). For the duplicate determinations, the markings of the reference points (including the coordinate system) were removed from the casts and new markings were made. The errors (*si*) were calculated with the formula:

$$si = \frac{\sqrt{\sum d^2}}{2n}$$

where *d* is the difference between the two measurements. The means of the errors for the right and left sides are given in Table 1.

Results

None of the variables studied differed significantly with gender. They were therefore combined for the further analyses.

Table 1. Accidental errors (*si*) of the method given in degrees and mm.

| | Before treatment | Effect of treatment |
|---|------------------|---------------------|
| Angle 1 (degree) | 4.3 | 5.2 |
| Angle 2 (degree) | 2.5 | 3.4 |
| Angle 3 (degree) | 2.0 | 2.6 |
| Distance 4 (mm) | 2.7 | 3.1 |
| Measurement 5 (mm) | | 0.5 |
| Measurement 6 (mm) | | 0.5 |
| Transverse distance between molars (mm) | | 0.3 |
| Centre of rotation: | | |
| <i>x</i> coordinate (mm) | | 2.0 |
| <i>y</i> coordinate (mm) | | 2.5 |

Angles 1–3 and the measurement according to Ricketts for the determination of the position of the first molar in the ideal occlusion group are given in Table 2. Only one variable showed a significant difference between the right and left sides. Angle 2 (according to Henry) was on average 2.1 degrees smaller on the left than on the right side ($0.01 < P < 0.05$). Because only one variable differed between the two sides, the table gives the mean values for the two sides. In all cases the line through the distobuccal and mesiopalatal cusps of the molar (according to Ricketts) passed distal of the midpoint of the contralateral canine. Note the large range for all variables.

Angles 1–3 and the measurement according to Ricketts in the treatment group are given in Table 3. Significant differences between the right and the left sides were recorded for all angles both before and after treatment and for distance 4 before treatment. In the table the variables are given as the mean of the two sides. The table also gives the treatment effect. The treatment effect was calculated for each individual tooth. The median effect is given in the table. The treatment effect did not differ significantly between the two sides with the exception of angle 1. For this variable, the median treatment effect was 18.5 degrees on the right and 15.2 degrees on the left side ($0.01 < P < 0.05$). All the treatment effects were highly significant ($P < 0.001$).

The line through the mesiopalatal and the distobuccal cusps of the molar (according to Ricketts) could be evaluated in relation to the right canine in 46 cases and relative to the left canine in 47 cases on the casts from before treatment. In all cases the line passed distal to the midpoint of the canine. The reason why the evaluation could not be done in all cases was that the deciduous canine was exfoliated and the permanent canine not yet erupted. On the casts made after treatment, evaluation relative to the right canine was possible in 43 cases. In six of these cases the line passed mesial to the midpoint of the canine. Evaluation relative to the left canine was possible in 42 cases. The line passed mesial to the midpoint of the canine in four of these cases.

Before treatment angle 2 and distance 4 were larger and angles 1 and 3 smaller in the treatment than in the ideal occlusion group ($P < 0.001$). As judged with all parameters used,

Table 2. Mean, SD, median and range for angles 1–3 (in degrees) and distance 4 (in mm) in the ideal occlusion group.

| | Mean | SD | Median | Range |
|-----------------------------|------|-----|--------|-----------|
| Angle 1 (Friel, 1959) | 61.5 | 5.7 | 62.0 | 46.5–71.4 |
| Angle 2 (Henry, 1956) | 11.1 | 4.6 | 10.2 | 2.2–20.4 |
| Angle 3 (Orton, 1966) | 9.9 | 5.0 | 10.8 | –0.4–23.0 |
| Distance 4 (Ricketts, 1969) | 11.4 | 4.0 | 10.7 | 2.2–21.1 |

Table 3. Median and range of angles 1–3 (in degrees) and distance 4 (in mm) before and after treatment as well as the median and range of the treatment effect.

| | Before treatment | | After treatment | | Treatment effect | |
|-----------------------------|------------------|------------|-----------------|------------|------------------|----------|
| | Median | Range | Median | Range | Median | Range |
| Angle 1 (Friel, 1959) | 54.0 | 42.7–66.8 | 71.3 | 57.9–84.2 | 16.5 | 1.2–32.6 |
| Angle 2 (Henry, 1956) | 18.5 | 8.7–27.5 | –0.7 | –10.7–11.3 | 17.3 | 9.8–31.9 |
| Angle 3 (Orton, 1966) | –1.3 | –14.8–12.3 | 18.5 | –3.6–31.4 | 18.8 | 1.2–45.8 |
| Distance 4 (Ricketts, 1969) | 19.9 | 10.3–32.4 | 6.5 | –2.8–13.4 | 13.3 | 6.1–22.6 |

the first molars were thus rotated mesiopalatally. After the treatment the opposite was true, i.e. angle 2 and distance 4 were smaller and angles 1 and 3 larger ($P < 0.001$). During treatment the molars were thus, on average, derotated to a position beyond that in the ideal occlusion group.

The y coordinate of the midpoint between the mesiobuccal and mesiopalatal cusps of the molar (measurement 5) describes the anteroposterior position of the tooth. Contrary to our expectations, many teeth moved mesially during the derotation (Fig. 5). The median values implied a mesial movement of 0.50 mm (range: 2.1 mm distal to 2.2 mm mesial) on the right and 0.21 mm mesial movement (range: 1.7 mm distal to 1.8 mm mesial) on the left side ($0.01 < P < 0.05$).

The median movement at the mesiobuccal cusp of the molar was on the right side 0.26 mm distally (change of y coordinate) and on the left side 0.48 mm distally ($0.001 < P < 0.01$). As shown in Figure 6, there was, however, a considerable variation, with the mesiobuccal cusp moving mesially in many cases. The range on the right side was from 3.0 mm distally to 1.5 mm mesially and on the left side from 3.1 mm distally to 1.5 mm mesially.

Measurement 7 (the x coordinate of the midpoint between the mesio-palatal and distobuccal cusps of the molar) was used to calculate the transverse distance between the right and left

molars. The median treatment effect was an expansion of 1.08 mm ($P < 0.001$). The effect varied between 1.2 mm contraction and 4.0 mm expansion (Fig. 7).

The centre of rotation of the molar during the derotation was found to vary widely (Fig. 8). The mean centre of derotation was located approximately midway between the distobuccal and distopalatal cusps.

Correlations

The interrelation of the treatment effects was evaluated by the calculation of correlations between the variables: change of angle 1 (according to Friel), and measurements 5, 6 and 7. Correlations to the size of angle 1 and to age at the start of the treatment as well as to the duration of the treatment were also calculated.

The treatment effects on the right and left sides were positively correlated (angle 1 $\rho = 0.37$, measurement 5 $\rho = 0.39$, $0.001 < P < 0.01$; measurement 6 $\rho = 0.30$, $0.01 < P < 0.05$). No significant correlation was found between the changes of measurement 7 on the two sides. The change of angle 1 was correlated to the size of this angle before treatment ($\rho = 0.41$, $P < 0.001$), the change of measurements 6 ($\rho = -0.38$, $P < 0.001$) and 7 ($\rho = 0.44$, $P < 0.001$) as well as the duration of the treatment ($\rho = -0.34$, $0.001 < P < 0.01$). A large derotation was thus made during a long

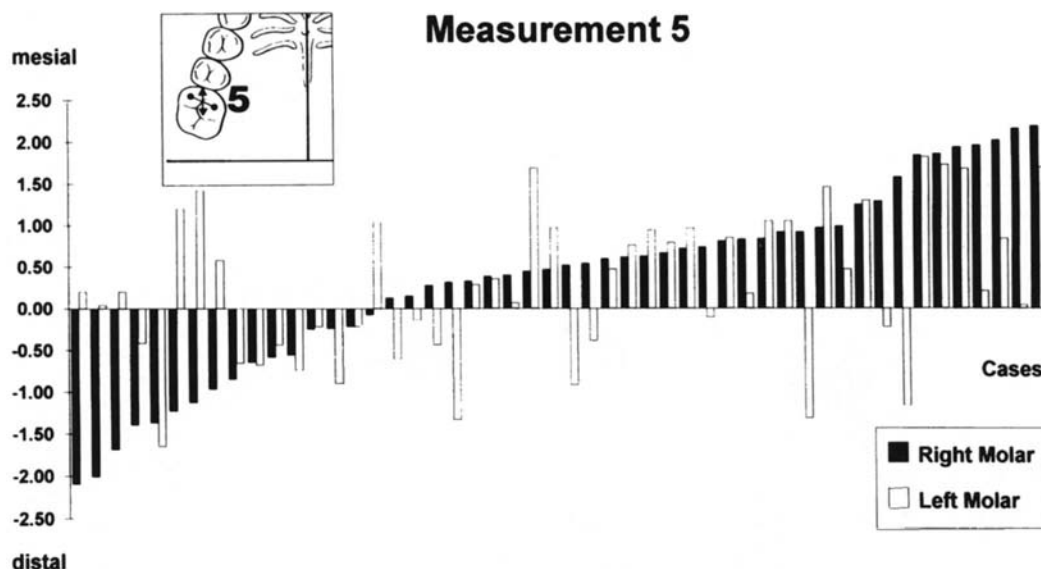


Figure 5 Anteroposterior movement of the midpoint between the mesiobuccal and mesiopalatal cusps of the first molar (measurement 5) in the individual cases.

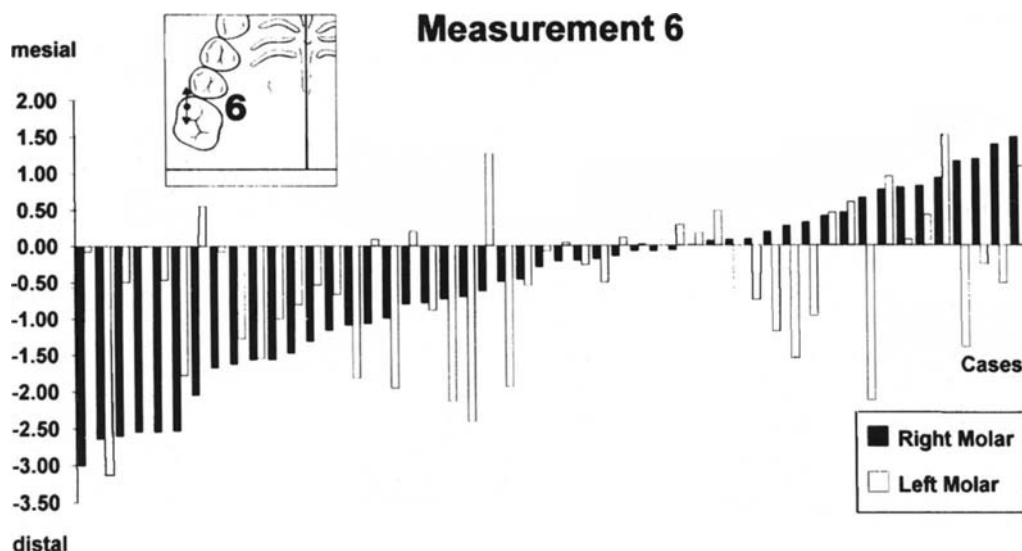


Figure 6 Anteroposterior movement of the mesiobuccal cusp of the first molar (measurement 6) in the individual cases.

treatment time in patients with markedly rotated molars at the start of the treatment and was coupled to a large posterior movement of the mesiobuccal cusp and to palatal movement of the molar.

No correlation was found between the changes of angle 1 and measurement 5. Measurement 5 is the y coordinate of the mid-

point between the mesiobuccal and mesiopalatal cusps of the molar and describes the anteroposterior position of the tooth. Thus, a gain or loss of space in the dental arch was not significantly correlated to the degree of derotation.

The changes of measurements 5 and 6 were strongly intercorrelated ($\rho = 0.95$, $P < 0.001$) and these changes were correlated to the change

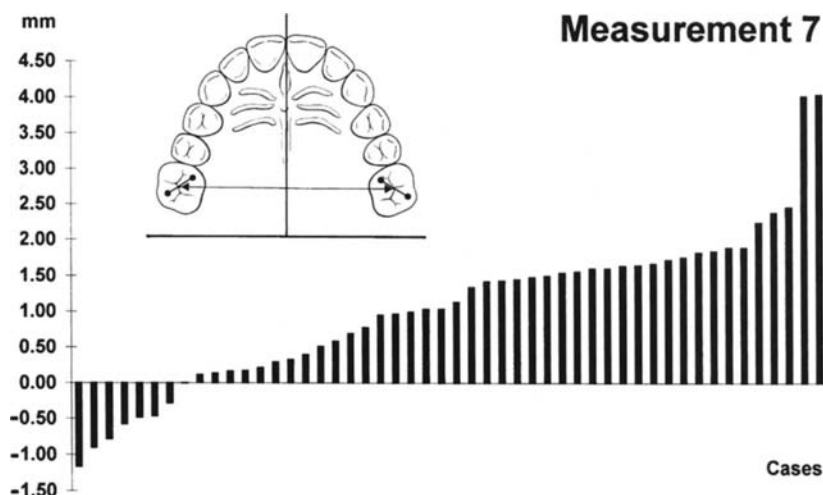


Figure 7 Change of transverse distance between the molars (based on measurement 7) in the individual cases.

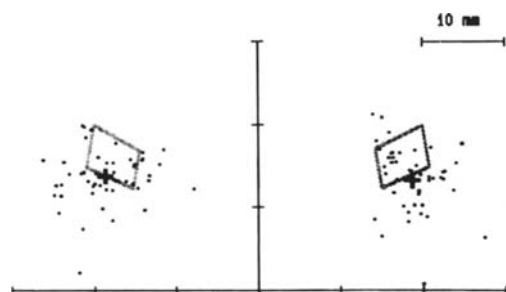


Figure 8 The location of the centre of rotation of the molar during derotation in the individual cases. All molars superimposed on the mesiobuccal cusp with mean locations of the other three cusps. + sign = mean centre of rotation.

of measurement 7 ($\rho = -0.31$, $0.001 < P < 0.01$; and $\rho = -0.36$, $P < 0.001$ respectively). Thus, a posterior movement of the midpoint between the mesiobuccal and mesiopalatal cusps or of the mesiobuccal cusp was coupled to palatal movement of the molar. No significant correlation was found between the duration of the treatment and changes of measurements 5–7. The effects of the treatment were not significantly correlated to age.

Discussion

The raphe line and median rugae points were used to establish the coordinate system for the measurements. It has been shown by Van der Linden (1978) and recently by Almeida *et al.* (1995) that these anatomical details are suffi-

ciently stable for their use as reference structures. The stability of a coordinate system based on the above mentioned structures over a short time span has also been verified by Ziegler and Ingervall (1989).

The errors of the method of the angles recorded as well as those for distance 4 and for the location of the centre of derotation were larger than those generally found in cephalometric profile analyses. Analyses of the individual cases of the duplicate determinations showed that the errors were to some extent due to difficulties in locating the raphe line in the posterior part of the palate. The fact that the reference points on the first molar were situated close to each other also contributes to the errors. Inaccuracies in the identification of these reference points are enlarged by the length of the reference lines constructed from them. An example is distance 4, which is measured on the contralateral side of the dental arch. The location of the centre of derotation was based on the movement of the reference points over small distances. It is therefore obvious that inaccuracies in the identification of the reference points will result in great errors in the determination of the centre of derotation. The errors in the recording of measurements 5 and 6 and of the transverse distance between the molars, on the other hand, were small and well within the range found in cephalometric investigations.

The accidental errors have a great influence on the individual measurements. Great errors will decrease the power of correlation analyses

because a large part of the total variation is due to the errors of the individual recordings. In the present study, several significant coefficients of correlation were found. A contributing factor may have been that many variables included in the correlation analysis have reference points in common. The marking of these reference points tends to artificially increase the coefficients of correlation (Björk and Solow, 1962).

While the errors of the method detract from the power of individual readings, their influence on the mean (or median) of a series of observations is less. The reason is that the effects of too large and too small recordings (due to the errors) cancel each other when a series of observations are made.

The mean (61.5 degrees) and the standard deviation of angle 1 in the ideal occlusion group were close to the values given by Friel (1959) for cases with normal occlusion (mean 58.2 degrees). The mean value of angle 2 (11.1 degrees) in the ideal occlusion group was identical to that given by Henry (1956) for excellent occlusion. The measurement of Orton (1966) was modified and therefore, direct comparison with the ideal value of 10 degrees given by Orton for the angle between a line tangent to the buccal surface of the molar and a line tangent to the buccal surfaces of the premolars is not possible. Our mean value for the modified measurement of Orton was 9.9 degrees. Because the first molars in the ideal occlusion group seemed to be in very good positions, as judged from angles 1 and 2, the angle used by us and by Orton seem to be compatible. The rule described by Ricketts (1969) for the position of the first molar seems to be questionable. In our ideal occlusion group the line through the distobuccal and mesiopalatal cusps passed on average 11.4 mm distal of the midpoint of the centre of the contralateral canine. This is considerably more than the transection of the distal surface of the canine as described by Ricketts, which would mean a distance of 0–4 mm distal of the midpoint of the canine.

Compared with the ideal occlusion group, the molars of the treatment group were markedly mesiopalatally rotated before treatment. The force system could efficiently derotate the molars in a relatively short time. A comparison after treatment with the ideal occlusion group revealed that the derotation had been exaggerated. A probable reason is that the molar posi-

tion was judged clinically with the rule of Cetlin (cited in McNamara and Brudon, 1993) that the buccal surfaces of the first molars should be parallel. Adherence to this rule results in overrotation of the molars, as is evident by comparison with the value of Henry (1956).

According to clinical experience and information in the literature (Henry, 1956; Ten Hoeve, 1985; Bailey, 1991), derotation of the molars will result in space gain in the dental arch. Our result did not confirm this as a general rule. On the contrary, the derotation led to mesial movement of many molars with no gain in space. We constructed the reference point for measurement 5 to approximate the mesial anatomical contact point of the molar. It may be that this construction was an unfortunate choice and that the movement of the true anatomical contact point would have revealed more space gain. On the other hand, the mesiobuccal cusp of the molar did not move distally as much as we had expected and even moved mesially in many cases. It is possible that the overrotation had a negative influence on the space gain, as measured by us, but the overrotation, on the other hand, would lead to greater distal movement of the mesiobuccal cusp. In spite of the disappointing general effect of the derotation on space gain and molar occlusion, it is evident from the range of variation that a considerable positive effect was obtained in some cases.

The reasons for the general lack of success with respect to space gain and molar occlusion are unclear. As shown in laboratory experiments (Ingervall *et al.*, 1996), it is difficult even under ideal conditions to balance the force system with equal moments on the two sides. This difficulty is presumably even greater in the clinical setting. In an unbalanced force system, the tooth with the largest moment will move mesially. One problem is that even if the degree of activation is checked by the alternate insertion of the arch in the lingual tubes, the final insertion implies a risk of some permanent deformation at one end of the arch. This is at the end already inserted in the tube and is due to the fact that the other end must be moved anteriorly past the tube. On the other hand, the positive correlation between the bilateral measurements 5 and 6 shows that the force system worked correctly, i.e. a large movement on one side was accompanied by a similar large movement on the other side.

Another reason for mesial movement of the molars may be pressure from the tongue on the palatal arch with a resulting mesial component of force as demonstrated by Ney and Göz (1993). These authors recorded, during swallowing, a mesially directed tipping moment on the first molars by a transpalatal arch with a mesially directed loop and a distally directed moment with an arch with a distally directed loop. The arches used by us had a mesially directed loop. It would, therefore, be interesting to compare the present results with those using an arch with a distally directed loop.

In the laboratory experiments, it was found that the derotation resulted in a moderate transverse contractive force (Ingervall *et al.*, 1996). This was not confirmed by clinical use because the median effect was a slight expansion. Only the correlation analysis confirmed the results of the laboratory experiments because a large derotation tended to result in palatal movement of the molar. The recommendation in the laboratory study not to compensate for transverse side effects until after the derotation seems to have been justified. The reason for the slight expansion is unclear but it is interesting to note that Baumann (1981) found a presumably passive Goshgarian palatal arch to result in 1.3 mm expansion over 6 months. Ney and Göz (1993) recorded intraorally a small transverse (expanding) force on the palatal arch during swallowing. It is, however, questionable if this small (1 N), intermittent force could be clinically relevant when exerted on a rigid transpalatal arch.

The centre of derotation of the molar was found to vary widely. This could, as discussed, be due to methodological problems but could also have biomechanical explanations. The median location of the centre of rotation was found to deviate from the presumed location lingual to the central fossa (Burstone, 1989). The centre was instead located more buccally, approximately midway between the distopalatal and the distobuccal cusps.

Our study has shown that rotated upper first molars can be derotated effectively with a transpalatal arch in a reasonable amount of time. The results of the derotation with respect to space gain and mesiodistal movement of the mesiobuccal cusp of the molar are unpredictable. In some cases a considerable gain of space and distal movement of the mesiobuccal cusp

are obtained. In other cases space is lost and the mesiobuccal cusp moves mesially. In the majority of the cases the derotation is accompanied by a slight expansion. A large derotation, however, tends to result in contraction.

Our results are at variance with the rule of Ricketts which says that a line through the mesiopalatal and distobuccal cusps of the molar should pass the distal half of the contralateral canine. In our ideal occlusion group the line passed considerably more distal. Our results are also at variance with the rule of Cetlin implying that the buccal surfaces of the first molars should be parallel when viewed from the anterior. In our study adherence to this rule resulted in overrotation of the molars.

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